# No-Till Drill Design for Atrazine Treated Soils

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## ABSTRACT

A no-till cereal grain drill was designed to enable use of the herbicide atrazine at high application rates to control weeds in wheat. Modified hoe openers moved atrazine treated soil and weed seed from the row leaving a herbicide free zone in which wheat could germinate and grow. Atrazine was concentrated between the rows to control weeds. Grain yields with a spear point hoe (1868 kg/ha) and the hoe preceded by a concave disc (1745 kg/ha) were not significantly different from a glyphosate check (1810 kg/ha) for atrazine applied at 1.1 kg/ha. Adding wings to the spear point hoe to move more soil laterally improved plant stands and forage yield compared with the standard spear point hoe opener.

## INTRODUCTION

Weed and volunteer crop growth must be controlled for conservation tillage practices to be successfully used for winter wheat *(Triticum aestivum* L.) Herbicides have been successfully used to control weeds during the three to four month fallow period between wheat crops in Oklahoma. However, winter annual weeds, particularly downy brome *(Bromus tectorum* L.) and cheat *(Bromus secalinus* L.) are difficult to control. Metribuzin (4-amino - 6-(1, 1-dimethylethyl) - 3-(methylthio) -1, 2, 4-triazine-5(4H)-one) is labeled for control of these weeds in Oklahoma. However, the herbicide is relatively expensive and weed control can be erratic. Metribuzin can cause significant injury to wheat.

Other triazine herbicides such as atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) can effectively control wheat and downy brome and cost less than metribuzin. Atrazine can be toxic to wheat at application rates which produce satisfactory weed control. However, the potential cost advantage that would result if atrazine is used in place of metribuzin stimulates the need to determine whether this herbicide could be selectively placed to establish an atrazine and weed free zone in which wheat could be seeded. Seeding in this zone would give wheat placement selectivity for atrazine, allowing the crop to germinate and emerge uninjured by the herbicide. One method of obtaining placement selectivity may be applying atrazine immediately prior to sowing wheat and removing atrazine treated soil from the vicinity of the row to create an atrazine free zone around the seed. Wheat could germinate and emerge in this zone without translocating significant amounts of the herbicide. Weed seeds would be removed from this zone and placed between the rows where atrazine would be concentrated. This approach has the potential for near or complete control of winter annual grasses in wheat, with minimal injury to the crop.

To determine if placement could be used to improve atrazine selectivity in wheat, research was conducted with the following objectives:

1. Design and construct a grain drill capable of removing atrazine treated soil from drill row.
2. Evaluate effects of removing atrazine treated soil from the drill row on plant populations, seedling stress, forage production, and grain yield of wheat.

This paper reports results of the research.

## REVIEW OF LITERATURE

Wittmuss et al. (1971) discussed a till-plant system which implemented the concept of removing crop residue and weed seed from the row to improve stand and to reduce competition from weeds within the row. They used a strip till-planter consisting of a rolling coulter to cut through crop residue followed by a sweep to remove residue and weed seed from the row. The crop was planted on ridges formed during cultivation the previous year. Corn and grain sorghum yields with the till-plant system were equal to yields with conventional tillage systems. The till-planter eliminated volunteer corn in the row by killing the growing plants with the sweep and by moving the seed from the row into the area between the rows, where it was killed during cultivation.

Wicks and Fenster (1967) applied several herbicides, including atrazine, ahead of a deep furrow drill, intending to incorporate the herbicides with the drill opener. They reported that applying the herbicides ahead of the drill caused less wheat injury than applying the same herbicides preemergence.

An extensive body of literature exists on no-till planter and drill design. Smooth coulters approximately 46 cm in diameter have been found to do the best job of cutting through heavy straw residues (Krall et al., 1978; Schaaf et al., 1980; and Vaishnav et al., 1982). Krall et al. (1978) reported that very narrow openers, such as double disc openers, and spike openers allowed straw to flow more smoothly and created more favorable seedbeds than spear points and 10 cm shovels. No difference were observed in performances of all types of press wheels in small grains. Schaaf et al. (1981) recommended that press wheel width be equal to or less than the width of the soil influenced by the opener.

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Wilkins et al. (1983) used a chloride tracer to determine effect of drill opener on the amount of surface material mixed into the seed zone. They reported that double disc openers and single disc openers left twice as much tracer in the row as hoe openers. Substantially more material was deposited within the seed zone with double disc and hoe openers.

Since minimizing atrazine contact with the wheat plant is essential to obtain placement selectivity, both the application rate and movement of the herbicide in the soil directly affect drill design and operation. Fenster et al. (1965) obtained 100% control of downy brome with atrazine applied at rates of 2.2 kg/ha. In a silt loam, atrazine rates of 2.2 kg/ha did not injure wheat planted 6 to 12 months later. In a fine sandy loam, wheat injury occurred at rates of 1.8 kg/ha. When atrazine was applied at 3.6 kg/ha, severe wheat injury occurred in both soil types.

Burnside et al. (1963) showed that atrazine in small amounts leached 30 to 45 cm into the soil. Occasionally, rates of 2 kg/ha injured wheat plants, but tillering increased to make up for plant losses. With furrow irrigation, atrazine moved laterally through the soil about 7.5 cm (Ashton, 1961). Birk and Roadhouse (1964) found that very little atrazine, applied at rates from 2 to 20 kg/ha, moved from the top 1.7 cm of soil. Slack et al. (1978) reported that s-triazines dissipated faster in no-till than in conventionally tilled corn.

## DRILL DESIGN

Atrazine can control cheat and downy brome at high application rates, but it can cause significant injury to wheat at these rates. If atrazine is to be used at high rates to control cheat in no-till wheat, a drill must be designed to remove surface applied atrazine and about 3.5 cm of treated soil from the drill row. Width of the treated soil band to be removed at planting may need to be as wide as 15 cm. At least two methods could be used to remove herbicide treated soil ahead of the drill openers. A modified hoe opener or sweep should be capable of pushing treated soil to either side of the row. A concave disc mounted ahead of the opener could move relatively large amounts of soil, depositing the material between the rows.

An experimental drill was constructed to evaluate selected components for use in removing atrazine treated soil from drill rows by either of the proposed methods. The drill consisted of a square tubular steel frame mounted on a tractor three point hitch. A modified Wil-Rich air seeder metering unit was attached to the frame (Fig. 1). The rubber roll metering unit, blower, and gasoline engine to drive the blower were retained. Seed and fertilizer hoppers were replaced with hoppers 1/4 the original capacity. The air manifold was rebuilt to fit between the metering unit and frame. Seed dropped from the metering rolls into individual seed cups for each row. Seed was then entrained into the air stream, exiting from the cups and traveling through hoses inserted into the furrow openers.

Eight opener units were constructed by welding 10 by 10 cm box beams to parallel 4-bar linkages. Each unit was bolted to the planter frame. Combinations of coulters, openers, and press wheels were bolted to the box beams for testing (Fig. 1).

Air cylinders provided a downward force of up to 2200 kN for each unit. A tractor engine driven air compressor supplied air to the cylinders.

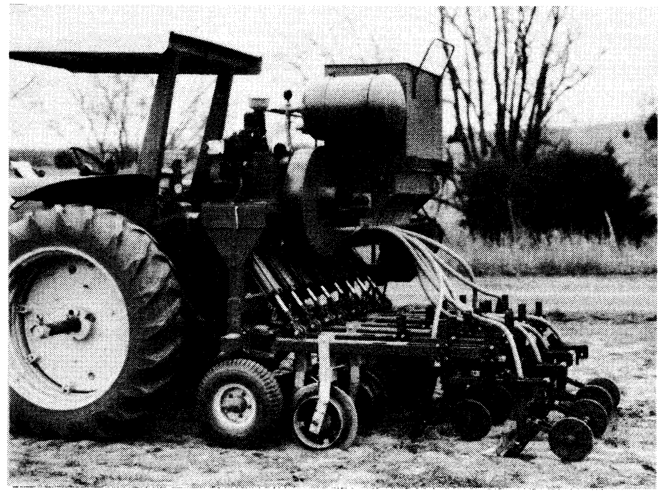

**Fig. 1—No-till drill with pneumatic seed delivery system, coulter gauge wheels, spear point hoe openers, and 2.5 by 25.0 cm press wheels.**

Components selected for evaluation included: Fleischer Manufacturing Company disc hillers with 46 or 56 cm diameter disc blades; John Deere LZ drill shanks and spear point hoe openers; Tye double disc openers; 2.5 cm by 25 cm cast iron center press wheels; and John Deere 10 cm by 30 cm rubber tire Vee press wheels. Fleischer Manufacturing Company 46 cm diameter coulter gauge wheels were bolted to the box beams of all units immediately behind the 4-bar parallel linkages. Disc hillers could be mounted immediately behind the coulter gauge wheels to remove treated soil and deposit it between drill rows (Fig. 2). Width and depth of treated soil removed could be varied by changing disc angle and operating depth.

Double disc or hoe openers were bolted to brackets which were clamped to the box beams. Openers could be spaced on 25 cm intervals or on paired row spacings (Fig. 3). Paired row spacings consisted of alternating 13 and 38 cm row spacings. The 38 cm spacings provided

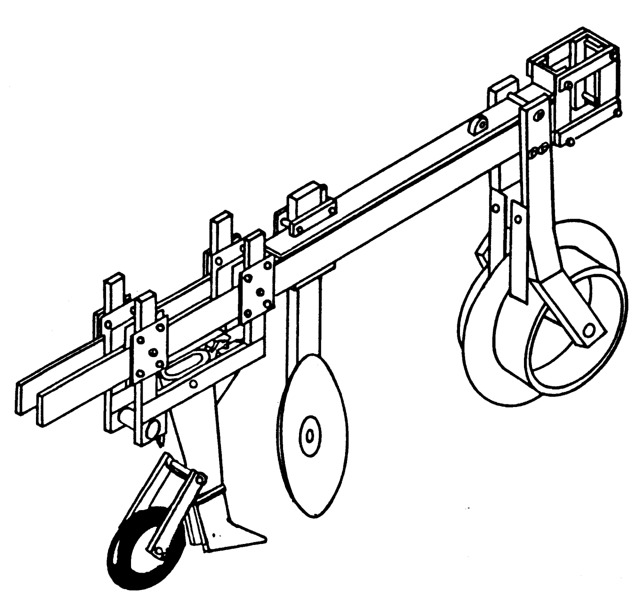

**Fig. 2—Single drill unit with coulter gauge wheel, 46 cm diameter concave disc to remove atrazine treated soil, spear point hoe opener, and 2.5 x 25.0 cm press wheel.**

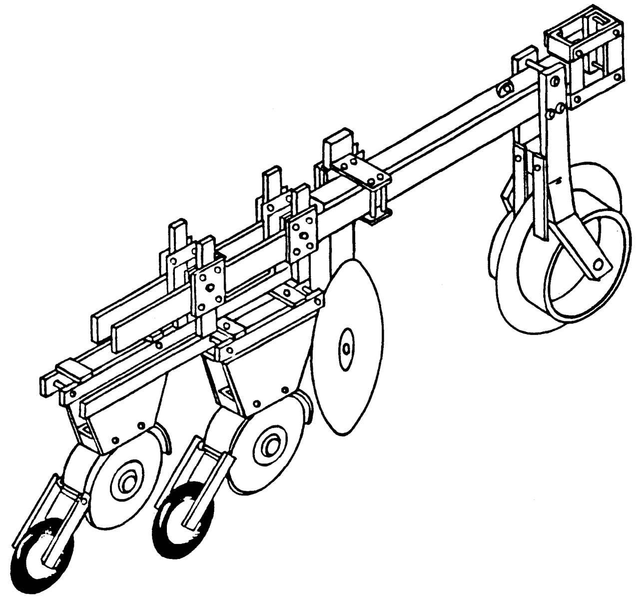

**Fig. 3—Single drill unit with coulter gauge wheel, 56 cm diameter concave disc to remove atrazine treated soil, paired double disc openers, and 2.5 by 25.0 cm press wheels.**

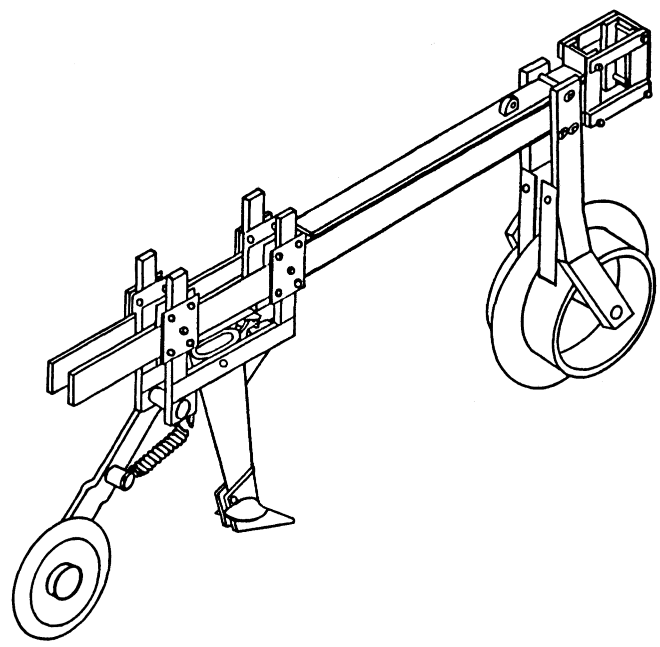

**Fig. 5—Single drill unit with coulter gauge wheel winged hoe to remove 5 cm wide strip atrazine treated soil, and 10 by 30 cm Vee press wheel.**

additional area for depositing soil removed by the disc hiller. The 46 cm diameter concave disc moved soil for each uniformly spaced opener; the 56 cm diameter disc moved soil for two openers when openers were paired. A 2.5 by 25 cm press wheel was attached behind each opener.

The spear point opener was used as a basis for developing a modified opener that combined the soil moving characteristics of the concave disc with a hoe furrow opener. The spear point cleared a 2.5 cm wide path through treated soil. Modified hoes were designed to clear 5 cm or 10 cm wide paths through treated soil. The 5 cm wide path was cleared by mounting wings on each side of the hoe opener. Wings were positioned so that treated soil was separated from clean soil as soil flowed around the opener (Fig. 4). This soil separation occurred above ground level, reducing vertical force

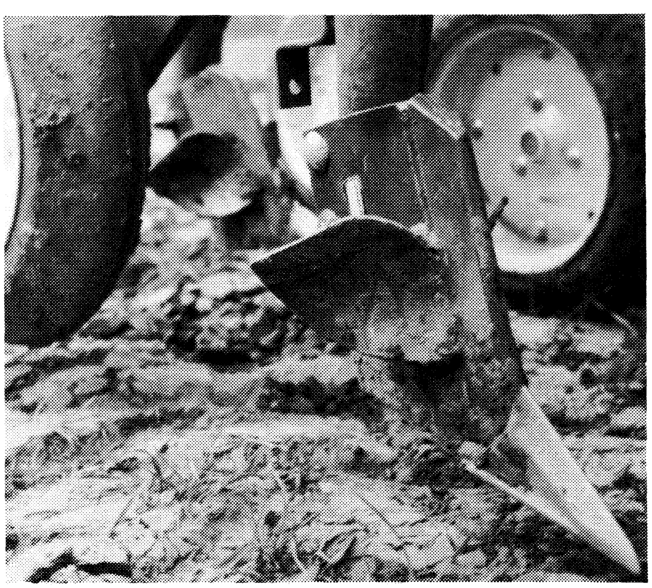

**Fig. 4—Winged spear point hoe opener designed to remove a 5 cm wide strip of atrazine treated soil and followed by 20 by 30 cm Vee press wheel.**

requirements by not forcing the wings into the soil. A 10 cm wide path was cleared by mounting larger wings on the hoe opener. To provide the additional soil movement, the wings were extended farther down on the opener. A 10 by 30 cm rubber tire Vee press wheel could be attached to firm the furrow walls to prevent treated soil from falling back into the furrow (Fig. 5). The 2.5 by 25 cm press wheel could also be attached to these units.

## METHODS AND PROCEDURE

Experiments were conducted to evaluate the seedling environment created by each set of components selected, and to determine if concave discs or winged hoe openers could be used to remove herbicide treated soil from the drill row while maintaining weed control. Components were tested in no-tillage and minimum tillage systems with no herbicide and in atrazine treated soil. The previous crop in all experiments was wheat.

### Drill Component Effects on Seed Environment

Six different component combinations were evaluated for effect on seedling environment under no tillage and minimum tillage conditions. Plots were planted on two dates at each location. Planter component combinations tested included:

1. Gauge coulter and spear point hoe opener with units on 25 cm row spacings (hoe treatment).
2. Gauge coulter and double disc opener with units on 25 cm row spacings (double disc treatment).
3. Gauge coulter followed by 46 cm concave disc and spear point hoe opener, units on 25 cm row spacings (concave disc hoe treatment).
4. Gauge coulter followed by paired spear point hoe openers (paired hoe treatment).
5. Gauge coulter followed by 56 cm concave disc, followed by paired spear point hoe openers (concave disc paired hoe treatment).
6. Gauge coulter followed by 57 cm concave disc followed by paired double disc openers (concave disc paired double disc treatment).

The no-tillage experiments were located at the Agronomy Research Station, Perkins, OK, on a Zaneis loam (thermic Udic Haplustolls; 58% sand, 24% silt, 19% clay, 5.3 pH, 1.1% organic matter). Plots were planted on October 2 and 19, 1984 with Tam W101 wheat *(Triticum aestivum* L.) and cut for grain yields on May 30, 1985.

Minimum tillage experiments were located at the Lake Carl Blackwell Experimental Range Area, Stillwater, OK, on a Port loam (thermic Cumulic Haplustolls; 32% sand, 42% silt, 26% clay, 6.1 pH, 1.5% organic matter). All plots were undercut with a Miller-W 3.3 m wide 2 section V-blade. Weeds were controlled with a Miller-W rodweeder with semi-chisels during the summer. At this location, TAM W101 wheat was planted on October 11 and November 6, 1984. Immediately prior to the second date of planting, plots were tilled with a Richardson mulch treader to control late germinating weeds. On March 22, 1985, the minimum tillage and no-till experiments were top dressed with 136 kg/ha ammonium nitrate fertilizer. The first planting date was harvested on June 10 and the second planting date on June 25, 1985.

A randomized complete block design with four replications was used at each location and date of planting. Stand counts were taken after the seedling emerged. Seedling stress was evaluated with the method described by Klepper et al. (1982). Klepper reported that adverse seedbed environmental conditions can cause tillers to be omitted or delayed, but main stem leaf development is not influenced by stress. Therefore, the number of tillers per plant can be used to indicate seedling stress. The number of main stem leaves per plant measured during emergence, indicates how fast seedlings emerge for each method. Plots were monitored throughout the growing season for plant growth and disease stress.

**Drill Component Effects on Atrazine Toxicity**

Separate experiments were conducted to evaluate the use of concave discs or the use of modified hoe openers to remove atrazine treated soils from the drill rows. The concave disc experiment to move atrazine treated soils from the row was located at the Lake Carl Blackwell Experimental Range Area, Stillwater, OK, in a McLain-Drummond complex soil (thermic Pachic Argiustolls-thermic Typic Natrustolls; 43% sand, 32% silt, 26% clay, 5.9 pH, 1.5% organic matter). Openers used were spear point openers on 25 cm row spacings (hoe opener), double disc openers on 25 cm row spacings (double disc opener), and the 56 cm concave disc followed by paired spear point openers (concave disc paired hoe opener). The 46 cm coulter with depth bands and the 2.5 by 25.0 cm press wheels were used with all openers. Atrazine rates were 0.6, 1.1, 2.2, and 3.4 kg/ha. In addition, one treatment consisted of glyphosate (N-(phosphonomethyl) glycine) applied preemerge at 1.1 kg/ha. Atrazine was applied on October 15 and plots were planted on October 17, 1984 with TAM 105 *(Triticum aestivum* L.) wheat. Plots were top dressed with 136 kg/ha of ammonium nitrate fertilizer on March 22, 1985.

A group balanced block on a strip plot design was used in this test (Gomez and Gomez, 1983). Planter combinations were evaluated in one strip, and atrazine rates were evaluated in the second strip. Initial emergence was recorded and plant growth was monitored throughout the growing period to determine effects of atrazine toxicity to wheat and weeds.

The spear point opener, 5 cm winged hoe opener, and 10 cm winged opener were used to evaluate the modified hoe openers (modified hoe experiment). Press wheels used were a 2.5 cm by 25.0 cm cast iron center press wheel, and a 10 cm by 30 cm rubber tire Vee type press wheel with springs to adjust down pressure.

The modified hoe experiments were conducted at two locations: the Agronomy Research Station, Perkins, OK, on a Teller loam (thermic Udic Argiustolls; 56% sand, 26% silt, 19% clay, 0.8% organic matter, 5.5 pH), the Teller loam location, and the Lake Carl Blackwell Experimental Range Area, Stillwater, OK, on a Port loam (32% sand, 42% silt, 26% clay, 1.5% organic matter, 6.0 pH), the Port loam location. At both locations wheat was seeded immediately after atrazine was broadcast sprayed at 0.0, 0.6, 1.1, 2.2, and 3.4 kg/ha. Plots were planted with Natadorus spring wheat *(Triticum aestivum* L.) on March 14, 1985 at the Teller loam location and March 15, 1985 at the Port loam location. A group balanced block in a strip plot design with one strip having two factors was used at both locations. The two factors evaluated in one strip were drill openers and press wheels. Atrazine rates were evaluated in the second strip. Both experiments were top dressed with 136 kg/ha of ammonium nitrate fertilizer on March 22, 1985. The experiments were harvested on July 2, 1985.

Experiments were analyzed using SAS (1979) statistical package. All analyses of variance were made with PROC ANOVA. The calculated significance probability for each main factor or interaction is recorded in parenthesis in the discussion. All means comparisons were made with Duncan's new multiple range test.

## RESULTS AND DISCUSSION

**Component Effects on Seed Environment**

There were no significantly different (0.05 level) values for number of main stem leaves for either tillage system (Table 1 and 2). The drill opener type and spacing and the use of the concave disc did not affect stand as determined by use of Klepper's et al. (1982) rating system. Main stem leaves and number of tillers were not counted for the second date of planting in the minimum tillage experiment because the site remained muddy as a result of heavy rainfall. The concave disc hoe opener was not used on the first planting date in the minimum tillag experiment because limited clearance between the disc and the hoe opener caused the drill to plug with wheat straw. Component stagger was increased and this drill configuration did not plug during planting on the second date.

Only the hoe opener in the first planting date in the no-till experiment had significantly more tillers than the other planter treatments for either tillage system (Table 1 and 2). However, the paired row treatments tended to rank lower than the evenly spaced treatments for both planting dates in the no-till experiment and the first planting date in the minimum till experiment. This indicates that the wheat in paired rows may have been under higher stress early in the season according to the Klepper et al. rating method.

TABLE 1. RESPONSE OF NO-TILL WHEAT SEEDED ON TWO DATES TO DRILL UNIT CONFIGURATION.

| Drill* | Stand, plants/row, m | | Main stem, leaves/row, m | | Tillers per plant | | Grain yield, kg/ha | |
|---|---|---|---|---|---|---|---|---|
| | Oct 2† | Oct 19 | Oct 2 | Oct 19 | Oct 2 | Oct 19 | Oct 2 | Oct 19 |
| Hoe | 50 a‡ | 59 a | 279 a | 288 a | 4.6 a | 1.7 a | 1979 ab | 1555 ab |
| Double disc | 56 a | 55 a | 292 a | 270 a | 3.3 b | 2.3 a | 2006 ab | 1671 ab |
| Concave hoe | 54 a | 57 a | 284 a | 282 a | 3.0 b | 2.0 a | 2262 a | 1867 a |
| Paired hoe | 56 a | 61 a | 283 a | 294 a | 2.7 b | 1.9 a | 1740 ab | 1513 b |
| Concave paired hoe | 56 a | 59 a | 291 a | 285 a | 2.8 b | 1.9 a | 1670 b | 1566 ab |
| Concave paired disc | 45 a | 53 a | 210 a | 276 a | 2.6 b | 1.9 a | 1929 ab | 1517 b |

*Hoe - spear point hoe opener on 25 cm row spacings; double disc - double disc opener on 25 cm row spacings; paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings; concave hoe - spear point openers on 25 cm row spacings preceded by a 46 cm concave disc; concave paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc; concave paired disc - double disc openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc.
†Date of planting.
‡Means preceded by the same letter are not significantly different within a column at the 0.05 level as indicated by Duncan's new multiple range test.

Paired spacing significantly reduced yields. The concave paired hoe opener ranked significantly lower than the highest yielding treatment, the concave hoe, in the first date of planting in the no-till experiment (Table 1). All other treatments were not significantly different from the concave hoe treatment. The paired hoe and concave disc paired double disc treatments ranked significantly lower than the highest yielding treatment, the concave hoe, in the second planting date. All other treatments were not significantly different from the concave hoe treatment. No significant difference in yields were shown for the first planting date in the minimum tillage experiment, but all paired row treatments ranked lower than the uniformly spaced treatments (Table 2). For the second planting date in the minimum tillage experiment, only the concave disc paired hoe and concave disc paired double disc treatment wheat yields ranked significantly lower than the highest yielding treatment, the double disc treatment.

TABLE 2. RESPONSE OF MINIMUM-TILLED* WHEAT SEEDED ON TWO DATES TO DRILL UNIT CONFIGURATIONS.

| Drill† | Stand, plants/row, m | | Main stem, leaves/row, m | Tillers per plant | Grain Yield, kg/ha | |
|---|---|---|---|---|---|---|
| | Oct 11‡ | Nov 6 | Oct 11 | Oct 11 | Oct 11 | Nov 6 |
| Hoe | 43 a∥ | 47 a | 288 a | 2.7 a | 1456 a | 1451 ab |
| Double Disc | 47 a | 52 a | 270 a | 2.6 a | 1412 a | 1717 a |
| Concave § Hoe | – | 39 a | – | – | – | 1567 a |
| Paired Hoe | 44 a | 46 a | 294 a | 2.2 a | 1475 a | 1393 ab |
| Concave Paired Hoe | 47 a | 34 a | 285 a | 2.3 a | 1323 a | 1060 bc |
| Concave Paired Disc | 46 a | 46 a | 276 a | 2.3 a | 1348 a | 827 c |

* Undercut with V-blade; tilled with rod weeder and mulch tiller to control weeds.
† Hoe - spear point hoe opener on 25 cm row spacings; double disk - double disc opener on 25 cm row spacings; paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings; concave hoe - spear point openers on 25 cm row spacings preceded by a 46 cm concave disc; concave paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc; concave paired disc - double disc openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc.
‡ Date of planting; excessive rainfall prevented collection of main stem leaf and tiller data for November 6 planting.
§ 46 cm concave disc followed by the single hoe opener plugged repeatedly in the loose straw on the October 11 planting; component spacings were changed to enable planting in the straw on November 6.
∥ Means followed by the same letter are not significantly different within a column at the 0.05 level as indicated by the Duncan new multiple range tests.

Rain water was observed to stand for longer periods in furrows created by both concave disc paired opener treatments than in the other treatments. Ponding stunted or drowned wheat in some plots. Maturity was delayed up to two weeks in some of the concave disc paired row treatments. Soil erosion was also observed where water was channeled by the 56 cm diameter concave disc furrow. Early in the growing season, reduction in residue borne foliage diseases were observed where the concave disk removed residue with the treated soil. These reductions were not apparent later in the growing season.

## Drill Component Effects on Atrazine Toxicity

In the experiment to determine the effect of removing treated soil to improve atrazine selectivity, plant stands obtained with the three openers were not significantly different when no atrazine was applied (Table 3). Application of atrazine at 0.6 and 1.1 kg/ha reduced wheat stands only when wheat was seeded with the double disc opener. Concave disc paired hoe wheat stands were significantly better than the double disc and hoe treatments at the 2.2 kg/ha application rate and were significantly better than the double disc treatment at the 3.4 kg/ha atrazine application rate.

Both drill type and herbicide treatment had significant effects on grain yield (Table 3). At the time of seeding,

TABLE 3. EFFECT OF USING A CONCAVE DISK FOLLOWED BY PAIRED SPEAR POINT HOE OPENERS TO REMOVE ATRAZINE TREATED SOIL* COMPARED TO DOUBLE DISC AND SPEAR POINT OPENERS IN NO-TILL WHEAT.

| Herbicide treatment | | Wheat stand, plants/row, m | | | Wheat yield, kg/ha | | |
|---|---|---|---|---|---|---|---|
| Herbicide | rate, kg/ha | Concave† disc | Double disc | Spear pt. hoe | Concave disc | Double disc | Spear pt. hoe |
| Check | — | 49 a-c§ | 42 a-d | 41 a-d | 1597 a-c§ | 843 df | 1077 b-e |
| Atrazine | 0.6 | 58 a | 38 b-d | 49 a-c | 1896 a | 1699 ab | 1708 ab |
| Atrazine | 1.1 | 57 a | 33 cd | 42 a-d | 1745 a | 1364 a-d | 1868 a |
| Atrazine | 2.2 | 39 b-d | 14 ef | 18 ef | 1414 a-d | 331 f-g | 713 e-g |
| Atrazine | 3.4 | 25 de | 3 f | 11 ef | 1045 c-e | 34 h | 168 gh |
| Glyphosate‡ | 1.1 | 47 a-c | 40 b-d | 51 ab | 1810 a | 1764 a | 1797 a |

*McLain-Drummond complex; 43% clay, 32% silt, 26% clay, 5.9 pH, 1.5% organic matter.

† Concave disc - paired spear point openers following concave disc on alternating 13 and 38 cm row spacings; double disc - double disc openers on 25 cm spacings preceded by a disc coulter with depth bands; spear point hoe - spear point hoe openers on 25 cm spacings preceded by a disc coulter with depth bands.

‡ Glyphosate applied pre-emerge.

§ Means followed by the same letter are not significantly different within rows or columns at the 0.05 level as indicated by Duncan's new multiple range test.

much of the cheat present had emerged. By comparing yields obtained by seeding with the concave paired hoe opener with the hoe and double disc openers in the check, it is apparent that the concave disc destroyed enough cheat to prevent yield reduction from this weed. With this opener, no atrazine rate tested reduced yield significantly when compared to the check. With the other openers, application of glyphosate after seeding to kill existing cheat increased wheat yields significantly. Compared to the check, application of 0.6 or 1.1 kg/ha of atrazine also increased yield. However, in contrast to the concave disc paired hoe opener, significant yield reductions occurred when atrazine was applied at 2.2 kg/ha.

In the modified hoe experiment, atrazine had a highly significant ($PR>F=0.0004$) effect on plant stand on the Teller loam, with increasing atrazine rates causing decreasing stands. Atrazine effect on wheat stand was also highly significant ($PR>F=0.0001$) on the Port loam. Openers signficantly affected wheat stands on both the Teller loam ($PR>F=0.0206$) and the Port loam ($PR>F=0.0281$). The 10 cm winged hoe had significantly better stands than the 2.5 cm or 5 cm hoe on the Teller loam (Table 5). Both the 5 cm and 10 cm winged hoe had significantly better stands than the 2.5 cm hoes on the Port loam.

Press wheels significantly affected wheat stands on both the Teller loam and the Port loam. On the Teller loam, Vee press wheel stands averaged 6.9 plant/row m and 2.5 by 25 cm press wheel stands averaged 4.9 plants/row m ($PR>F=0.0620$). On the Port loam, Vee press wheel stands averaged 26.9 plants/row m and 2.5 by 25 cm press wheel stands averaged 23.3 plants/row m ($PR>F=0.0643$).

There was a significant ($PR>F=0.0113$) atrazine application rate by opener interaction for wheat stand on the Teller loam. There was also a significant ($PR>F=0.0110$) atrazine rate by press wheel interaction for wheat stand on the Teller loam. The atrazine rate by opener by press wheel interaction for wheat stand was a significant factor ($PR>F=0.0152$) on the Port loam. The 10 cm winged hoe openers with either press wheel types were not significantly different from the best check stands for application rates as high as 1.1 kg/ha on the Teller loam (Table 4). There were no significant differences in wheat stands among the 5 and 10 cm

TABLE 4. RESPONSE OF SPRING WHEAT TO WIDTH OF THE STRIP OF ATRAZINE TREATED SOIL REMOVED BY THE HOE OPENER AND TO PRESS WHEEL TYPE IN A TELLER LOAM (56% SAND, 26% SILT, 19% CLAY 0.8% ORGANIC MATTER, 5.5 pH) AND A PORT LOAM (32% SAND, 42% SILT, 26% CLAY, 1.5% ORGANIC MATTER, 6.0 pH).

| Press* wheel | Opener width | Appli. rate, kg/ha | Wheat stand, plants/row, m Teller | Port | Forage yield, kg/ha Teller | Port |
|---|---|---|---|---|---|---|
| 2.5 | 2.5 | 0.0 | 6.0 b-f† | 24 c-f | 85 a-f | 330 a-f |
| | | 0.6 | 3.7 f-h | 29 a-d | 65 b-g | 369 a-d |
| | | 1.1 | 4.2 e-h | 22 c-g | 34 e-g | 256 a-i |
| | | 2.2 | 0.8 h | 21 d-h | 10 fg | 328 a-f |
| | | 3.4 | 1.4 h | 15 e-h | 1 g | 123 f-i |
| Vee | | 0.0 | 12.2 a-e | 30 a-d | 104 a-e | 340 a-e |
| | | 0.6 | 6.0 b-h | 24 c-f | 58 c-g | 340 a-e |
| | | 1.1 | 5.0 d-h | 26 a-e | 53 d-g | 289 a-h |
| | | 2.2 | 1.2 h | 19 gh | 8 fg | 221 b-i |
| | | 3.4 | 0.2 h | 13 f-h | 1 g | 87 hi |
| 2.5 | 5.0 | 0.0 | 7.4 a-f | 36 ab | 52 d-g | 334 a-e |
| | | 0.6 | 6.0 b-h | 32 a-d | 45 e-g | 348 a-e |
| | | 1.1 | 5.9 b-h | 30 a-d | 38 e-g | 332 a-f |
| | | 2.2 | 0.7 h | 13 f-h | 16 fg | 201 c-i |
| | | 3.4 | 2.5 h | 11 h | 2 g | 72 i |
| Vee | | 0.0 | 13.6 a-c | 30 a-d | 125 a-d | 346 a-e |
| | | 0.6 | 14.0 ab | 37 a | 131 a-c | 380 a-c |
| | | 1.1 | 5.4 c-h | 37 a | 98 a-e | 290 a-f |
| | | 2.2 | 0.8 h | 26 a-e | 10 fg | 194 c-i |
| | | 3.4 | 1.5 h | 12 gh | 1 g | 156 e-i |
| 2.5 | 10 | 0.0 | 12.8 a-d | 29 a-d | 136 ab | 355 a-e |
| | | 0.6 | 10.7 a-g | 30 a-d | 86 a-f | 435 a |
| | | 1.1 | 10.2 a-g | 25 b-e | 51 d-g | 383 a-c |
| | | 2.2 | 0.7 h | 16 e-h | 6 g | 289 a-h |
| | | 3.4 | 0.9 h | 16 e-h | 5 g | 112 g-i |
| Vee | | 0.0 | 15.4 a | 34 a-c | 137 ab | 459 a |
| | | 0.6 | 14.6 a | 34 a-c | 146 a | 420 ab |
| | | 1.1 | 11.9 a-f | 37 a | 94 a-c | 374 a-d |
| | | 2.2 | 0.7 h | 27 a-c | 8 fg | 284 a-h |
| | | 3.4 | 0.7 h | 17 e-h | 1 g | 167 d-i |

*2.5 - 2.5 by 25 cm press wheel; Vee - 10 by 30 cm Vee profile press wheel.

†Means followed by the same letter are not significantly different within column at the 0.5 level as indicated by Duncan's new multiple range test.

TABLE 5. SPRING WHEAT STANDS AND FORAGE YIELDS ON TWO SOIL TYPES* FOR THREE DRILL OPENERS WITH STANDS AVERAGED OVER FIVE ATRAZINE APPLICATION RATES†.

| Opener‡ width, cm | Stand, plants/row, m | | Forage, kg/ha | |
|---|---|---|---|---|
| | Teller loam | Port loam | Teller loam | Port loam |
| 2.5 | 4.1 a§ | 22.3 a | 42 a | 268 a |
| 5.0 | 5.8 a | 26.4 b | 52 a | 265 a |
| 10.0 | 7.9 b | 26.5 b | 67 a | 328 b |

* Teller loam - 56% sand, 26% silt, 19% clay, 0.8% organic matter, 5.5 pH. Port loam - 32% sand, 42% silt, 26% clay, 1.5% organic matter, 6.0 pH.

† Atrazine application rates 0.0, 0.6, 1.1, 2.2, 3.4 kg/ha.

‡ Opener width - width of strip of atrazine treated soil removed by a spear point hoe, a 5 cm winged hoe, and a 10 cm winged hoe.

§ Means followed by the same letter are not significantly different within columns at the 0.05 level as indicated by Duncan's new multiple range test.

winged hoe treatments with Vee press wheels and the best check stands for atrazine rates as high as 2.2 kg/ha on the Port loam.

Atrazine application rate was a highly significant factor decreasing forage yield on the Teller loam (PR>F=0.0003) and on the Port loam (PR>F=0.0001). Press wheels were a significant factor (PR>F=0.0287) affecting forage yield on the Teller loam. The 2.5 by 25 cm press wheel treatments averaged 42.1 kg/ha, while the Vee press wheel treatment averaged 65 kg/ha for all atrazine rates and openers. Openers significantly (PR>F=0.0392) affected forage yield on the Port loam. The 10 cm winged hoe treatment averaged over all atrazine and press wheel treatments, ranked significantly higher than the other openers on the Port loam (Table 5). The 10 cm winged hoe treatment also ranked highest on the Teller loam, but the difference was not significant. On the Teller loam, the 5 cm and 10 cm winged hoes with the Vee press wheels forage yields were not significantly different from the best check treatments for rates as high as 1.1 kg/ha (Table 4). On the Port loam, both 10 cm winged hoe treatments forage yields were not significantly different from the best check treatments for rates as high as 2.2 kg/ha.

Atrazine rate was a highly significant factor affecting grain yields (PR>F=0.0001 on both soils) with increasing atrazine rates causing decreased yields. Drill opener and press wheel main factors and interactions were not significant for grain yields. No significant trends or patterns could be detected among treatment means using Duncan's analysis. Normally, spring wheat is not grown in Oklahoma. The wheat was planted three weeks late because of wet soils. The weather was hot and dry during grain filling and there appeared to be a substantial disease problem. The combination of these factors depressed grain yields and minimized differences between treatments.

Soil type appeared to have a substantial effect on the maximum allowable atrazine rate. In the Port loam the 10 cm winged hoe and Vee press wheel could be used with atrazine rates as high as 2.2 kg/ha without significant decrease in wheat stand (Table 5). However, in the Teller loam, the 10 cm hoe and Vee press wheel could only be used with atrazine rates no higher than 1.1 kg/ha without significant reductions in wheat stand and forage yield (Table 4). A similar relationship existed for most other opener, press wheel combinations.

## SUMMARY AND CONCLUSION

Atrazine treated plots sown with the 56 cm concave disc followed by paired spear point hoe openers had significantly higher wheat stands and yields than plots sown with spear point hoe and double disc openers at 25 cm row spacings. Plots planted in atrazine treated soil with the 10 cm winged hoe and the Vee press wheel produced higher stands and more forage than plots sown with a spear point hoe, or 5.0 cm winged opener. However, drill component tests on untreated soil indicated that planting with the double disc or spear point hoe openers in paired row spacings with and without the 56 cm concave disc openers produced lower yields than 25 cm row spaced openers. Plots planted with the concave disk paired opener combinations were more susceptable to the soil erosion and ponding. Atrazine injury occured at lower application rates in soil with a higher percentage of sand. The best combinations of drill components for removing atrazine treated soil was the 46 cm gauge coulter, 10 cm winged hoe opener, and Vee press wheel combination which removed a 10 cm wide strip of atrazine treated soil from the row.

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